Center Innovation Fund: LaRC CIF

Co-Cure-Ply Resins for High Performance, Large-Scale Structures

Completed Technology Project (2015 - 2016)

Project Introduction

Large-scale composite structures are commonly joined by secondary bonding of molded-and-cured thermoset components. This approach may result in unpredictable joint strengths. In contrast, assemblies made by co-curing, although limited in size by the mold, result in stable structures, and are certifiable for commercial aviation because of structural continuity through the joints. Multifunctional epoxy resins were prepared that should produce fully-cured subcomponents with uncured joining surfaces, enabling them to be assembled by co-curing in a subsequent out-of-autoclave process. Aromatic diamines were protected by condensation with a ketone or aldehyde to form imines. Properties of the amine-cured epoxy were compared with those of commercially available thermosetting epoxy resins and rheology and thermal analysis were used to demonstrate the efficacy of imine protection. Optimum conditions to reverse the protecting chemistry in the solid state using moisture and acid catalysis were determined. Alternative chemistries were also investigated. For example, self-immolative polymers and photo initiated catalysis would be expected to minimize liberation of volatile organic content upon deprotection and avoid residual reactive species that could damage the resin.

The Challenge: Airframe manufactures install mechanical fasteners in adhesively bonded joints to comply with federal aviation regulations. An average commercial aircraft contains several miles of adhesively bonded joints and therefore thousands of redundant fasteners. An alternate means of assembling large-scale composite structures to meet federal regulations is needed to realize the ultimate potential of composites to reduce cost and increase aircraft performance. Removing redundant fasteners may reduce the part count by 120,000 parts and the weight of the aircraft by 5000 lbs. (2%). Multi-functional materials to improve flight efficiency and safety are core components of NASA’s mission and align well with Langley’s strategic investment plan.

The State-of-the-art vs. the proposed method: Large-scale composites structures are prepared by laying up prepreg in a mold and curing it in an autoclave. For thermosetting polymers (e.g. epoxies) the resin reflows upon heating and then undergoes a curing reaction (cross-linking) to form a solid part. If two components are laid-up together and cured simultaneously, this is known as co-curing (see figure). Co-cured assemblies do not require redundant fasteners because the joints are formed seamlessly as the resin re-flows and eventually cures through the formation of new chemical bonds. The use of the co-cure process is limited by the size of the autoclave or oven being used to mold and cure the part. The proposed work will develop a multifunctional epoxy resin that will enable sub-structures to be fully cured while leaving the joining surfaces uncured for assembly in a subsequent, out-of-autoclave, co-cure process. The proposed multifunctional resin, combined with fiber reinforcement, can be used to manufacture composite structures

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Langley Research Center (LaRC)

Responsible Program:

Center Innovation Fund: LaRC CIF

that match the performance of state-of-the-art, mono-functional materials.

The Method Details: The proposed material will be prepared by protecting the reactive groups in a commercially available epoxy resin. Specifically, the amine functional groups of an epoxy hardener will be protected by condensation with a ketone to form an imine. The imine protecting groups will not react with epoxide groups, preventing the resin from curing. After the sub-structures are cured, the imine protecting groups will be removed by exposure to water vapor. Once de-protected, the amine groups will react with epoxides to form a solid, epoxy plastic.
The Work Package: Initial demonstrations will be limited to small scale reactions (1 to 10 grams of material). Spectroscopic techniques will be used to verify the success of protecting and de-protecting chemistry. The ability of the resin to prevent curing, undergo de-protection, and cure completely will be assessed by thermomechanical analysis. In a subsequent project, the novel resin would be produced in larger quantities and used to make prepreg, which could be used to prepare composite coupons and assess interlaminar fracture toughness.

The Risk: Although protecting group chemistry is well known, a significant risk is presented by attempting to introduce new resin systems to aerospace structures. Usually decades of testing and many practical demonstrations are required before new materials are certified for flight. This risk can be reduced by making the minimum possible modification to resin components that are currently in use.

Anticipated Benefits

An alternate means of assembling large-scale composite structures to meet federal regulations is needed to realize the ultimate potential of composites to reduce cost and increase aircraft performance. Removing redundant fasteners may reduce the part count by 120,000 parts and the weight of the aircraft by 5000 lbs. (2%). Multi-functional materials to improve flight efficiency and safety are core components of NASA’s mission and align well with Langley’s strategic investment plan.

Project Management

Program Director:

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Program Manager:

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Principal Investigator:

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Technology Maturity (TRL)

Start: **1**
Current: **1**

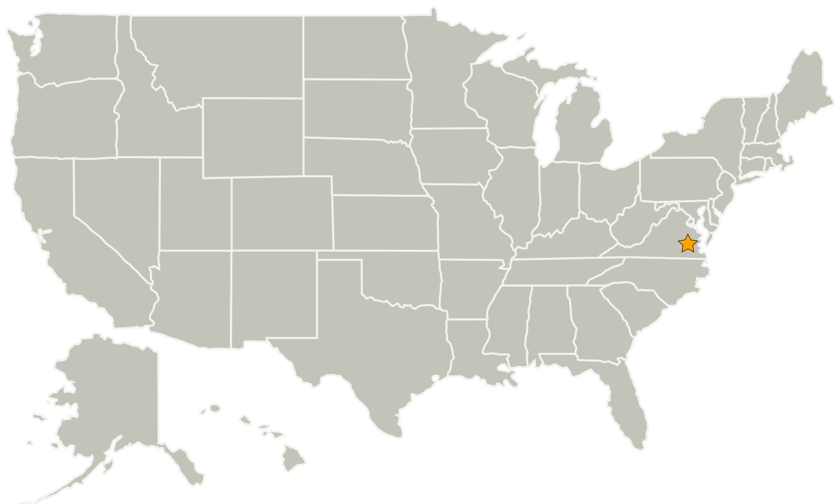
1	2	3	4	5	6	7	8	9
Applied Research			Development			Demo & Test		

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └ TX12.4 Manufacturing
    └ TX12.4.1 Manufacturing Processes

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
⭐Langley Research Center(LaRC)	Lead Organization	NASA Center	Hampton, Virginia